RUBBER LABORATORY

MARE ISLAND NAVAL SHIPYARD

DEPARTMENT OF THE NAVY
BUREAU OF SHIPS

TECHNICAL REPORT

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DEVELOPMENT OF DAMPING TREATMENTS FOR NEW CONSTRUCTION SUBMARINES

PROGRESS REPORT NO. 12

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RUBBER LABORATORY

MARE ISLAND NAVAL SHIPYARD

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ABSTRACT

This investigation was concerned with the development of elastomeric materials to replace chromated felt in constrained-layer treatments for damping heavy plating in new construction submarines. A treatment having a weight ratio to the treated plate of 1 to 4 and utilizing a perforated nitrile rubber damping layer was found to be almost as effective as Treatment 198, a similar treatment developed by the Rubber Laboratory which utilized chromated felt. The new treatment, designated Treatment 227, consisted of an aluminum constraining layer 1-1/4 inches thick and a perforated nitrile rubber damping layer 1/16 inch thick which was made from stock 384-584. It was fastened by means of 1/2 inch studs on 12 inch centers to 1-3/4 inch thick steel plate.

The average damping at 75°F for Treatment 227 over the frequency range of 50 to 2000 cps was 6.2% of critical as compared to 6.5% of critical for Treatment 198. It was found that the damping behavior of the nitrile rubber layer was affected similarly to the chromated felt by temperature change. Maximum damping occurred at 65°F. Substantially lower damping were obtained at 35° and 120°F. Work is continuing on the development of damping treatments which will be efficient over the temperature range of 35° to 120°F.

REFERENCES

(a) BUSHIPS ltr F013-13-01 Ser 634C1-1277 of 15 Dec 1961
(b) BUSHIPS ltr F013-13-01 Ser 634C1-516 of 29 May 1962
(c) NAVSHIPYD MARE Rubber Laboratory Report 9-39 of 29 March 1951; "Transmission of Mechanical Vibrations through Various Rubbers"

INTRODUCTION

1. This is the twelfth progress report by the Rubber Laboratory on the development of damping treatments for heavy plates on new construction submarines. The investigation was authorized by the Bureau in reference (a). The authorization was extended in reference (b). The present work dealt with the damping of 1-3/4 inch thick steel bars by constraining layer treatments. Previous work by the Laboratory on the same subject was described in Rubber Laboratory Reports Nos. 94-12, -22, -23, -24, -25, -27, -29, -33, -36, and -37.

2. The best treatment obtained in the previous work for 1-3/4 inch thick steel bars with a weight ratio of treatment to steel of 1:4 was Treatment 198. It consisted of a 1-1/4 inch thick constraining layer of aluminum, and a 1/4 inch thick constrained layer of chromated felt. The effectiveness of the treatment, however, changed markedly with temperature. Maximum damping was at 75°F, but damping at 35° and 120 F was one third or one fourth of the damping at 75°F. The objective of the present work was to develop an effective damping material for the constrained layer which would be less sensetive to temperature than chromated felt.

3. The effects on damping of the constraining pressure, and of factors associated with the shape and dimensions of the constrained layer were studied, in order to establish the optimum conditions for damping by the treatments. Of particular interest in this study was the relationship between damping and the "shape factor", i.e., the ratio of the load bearing area in contact with the steel bar to the

free area of the rubber. Constrained layers of varying shape factors were studied for this purpose.

RUBBER COMPOUND FOR CONSTRAINED LAYER

4. It is assumed that in the type of damping treatments used in this work, the major part of the damping is due to energy loss in the constrained layer. Consequently, a constrained layer compound possessing a high loss modulus would be a promising material for this purpose.

5. Previous work by the Laboratory, reference (c), indicated that vulcanizates of nitrile rubbers with high acrylonitrile content possess high loss moduli. A nitrile rubber of this type, Paracril D, was selected for the preparation of constrained layers in the present investigation. Five compounds of this rubber were prepared, and stock 384-584 was selected as the most promising material. The recipe for this stock is given below.

Stock 384-584

Paracril D	100
Hycar 1312	10
Philblack A	60
Protox 166	5
Stearic acid	1
Neozone D	1
Thionex	0.6
Sulfur	1.5

CURE: 20 minutes at 320°F

DESCRIPTION OF TREATMENTS

6. Each test assembly consisted of a steel bar, 96 x 6 x 1-3/4 inches, a damping treatment consisting of a constraining aluminum bar, 92 x 6 x 1-1/4 inches, and a constrained layer made of stock 384-584, sandwiched between the steel bar and the aluminum bar. The treatment was fastened to one face of the steel bar by means

of 1/2 inch diameter studs and lock nuts. The studs were welded to the steel bar along the middle line of one of its faces. They were spaced 12 inches apart. The test assembly was hung from steel beams by two ropes, 5 feet long. A constraining pressure was applied to the treatments by tightening the lock nuts with a torque wrench.

7. Constrained layers of various designs and thicknesses were used in order to study the effects of the shape factors on damping. Two types of constrained layers were used, namely, solid sheets, and perforated sheets with a square grid pattern. The perforated sheets had mold flash, a few thousandths of an inch thick, on one of their faces. The various types of constrained layers used are described in Appendices 1 and 2.

TESTING PROCEDURES

8. The procedure for determining damping was described in details in Report No. 94-36. The essential features of the testing procedure were as follows: An electromagnetic shaker was attached to one end of the treated bar, and an accelerometer pickup at the other end. The bar was vibrated by means of the shaker. The frequency of the vibration was gradually increased until a resonance frequency was reached, as indicated by the output of the pickup. The current to the shaker was then shut off by means of a relay, and the pickup signal of the decaying vibration of the test assembly was projected on a Memoscope screen. The signal was first passed through an amplifier, a filter, and finally through a log amplifier, prior to its passage through the Memoscope. The instrumentation used for determining damping is shown schematically in Appendix 3.

9. The angle of the projected wedge-shaped signal with the time axis of the Memoscope screen was measured, and the damping was determined according to the following equation:

$$\text{Percent of critical damping} = K \frac{\tan A}{t\ f}$$

K = a constant, which includes characteristics of the Memoscope and associated electronic equipment

A = angle of the wedge shaped signal with the time axis of the Memoscope

t = sweep time in seconds per division of the Memoscope

f = frequency of vibration, in cycles per second

10. A constraining pressure was applied to the treatment, after its application to the steel bar, by tightening the nuts on the studs with a torque wrench. The formula for converting inch-pounds of torque into the corresponding pressure was given in Report 94-36. Damping was determined from one hour to several days after application of the constraining pressure. Once a given constraining pressure was applied, it was not further adjusted during the test. The constraining pressures indicated herein thus refer to the initially applied pressures. The actual pressures during the damping measurements were probably somewhat lower than the initial pressures due to stress relaxation.

11. In the tests dealing with the effect of constraining pressure on damping, each treatment was successively subjected to pressures of 15, 40, and 73 psi, respectively. Damping was determined at each of these pressures.

RESULTS

Effect of Constraining Pressure

12. Constrained layers of solid rubber sheets, 1/16, 1/8, and 1/4 inch thick, were used for the study of the effect of constraining pressure on damping. The results are tabulated in Appendix 4. There was a slight tendency for damping to increase as the constraining pressure was raised from 15 to 73 psi. The largest increase, about 30%, occurred in Treatment 220, which utilized a 1/4 inch

thick constrained layer. The effect of pressure on damping in most intermediate pressure steps was insignificant.

Effect of Constrained Layer Thickness

13. The data of Appendices 4 and 5 indicate that damping in the treatments which utilized solid sheet constrained layers tended to increase as the thickness of the constrained layer decreased. The highest dampings were obtained with 1/16 inch thick layers. A fourfold decrease in thickness raised damping by about 10% to 30%, depending on the constraining pressure.

Effect of Shape Factor of Constrained Layer

14. The data pertaining to the relations between damping and shape factor are presented in Appendices 1 and 5. The data of Appendix 1 indicate that for any given thickness of the constrained layer, the perforated sheets with the lower shape factors yielded higher damping than the solid sheets with the higher factors. This effect was most pronounced in the case of the 1/16 inch thick sheets. It was less significant in the case of the 1/8 and 1/4 inch thick sheets, even though the perforated layers of these thicknesses possessed the lowest shape factors of all of the tested sheets.

15. Further inconsistancies in the relations between damping and shape factor were exhibited by Treatments 225 and 227 with 1/16 inch thick constrained layers. Treatment 225 with a factor of 1.3 exhibited less damping than Treatment 227 with the higher factor of 2.85.

16. These inconsistancies may stem in part from the fact that in the present tests it was not possible to separate the effect of the shape factor from the effects of other factors such as thickness, the mass of rubber per unit area of treatment (mass factor), and the ratio of the load bearing area of the constrained layer in contact with the steel bar (or aluminum bar) to the treatment

area (area factor). Whenever the constrained layer design was altered in order to change the bound to free area ratio the other factors were also altered.

Effect of Mass Factor of Constrained Layer

17. The relative mass factors of the various constrained layers were determined by assigning the value of 1 to the mass of rubber per square inch of treatment of the 1/16 inch thick solid sheet layer. The data of Appendix 1 indicate that there was a tendency for damping to increase as the mass factor decreased. Treatment 227 deviated from this behavior. This tendency might be related in part to the thickness of the layer, since the thickness was also decreased as the mass factor decreased.

Effect of Area Factor of Constrained Layer

18. It was of interest to find that the highest damping was obtained with a treatment (Treatment 227) in which only 75% of the steel bar area was in contact with the load bearing surface of the constrained layer (area factor of 0.75). The average damping of this treatment was about 35% higher than the average damping obtained with a treatment of solid sheet rubber (Treatment 221) of the same thickness, in which the steel and aluminum bars contacted the rubber layer over the entire area of the treatment.

Effect of Temperature

19. Treatment 225, utilizing a perforated constrained layer, 1/16 inch thick, was used for the study of the effect of temperature on damping. An initial constraining pressure of 40 psi was applied to the treatment. The most significant data of this study are presented in Appendices 7, 8 and 9.

20. The data shown in Appendix 9 indicate that Treatment 225 exhibited a temperature dependence similar to that of Treatment 198, which utilized chromated felt as a constrained layer. Treatment 198 is the best damping treatment obtained to date for 1-3/4 inch thick steel bars with a weight ratio of treatment to steel of 1:4.

21. Both treatments exhibited a sharp damping maximum in the temperature range between 35° and 120°F. In the case of Treatment 198 this maximum occurred at about 75°F. The maximum for Treatment 225 was at about 65°F. Average percent of critical damping over the frequency range between 50 and 2000 cps at the optimum damping temperature was 6.5% for Treatment 198, and 6.2% for Treatment 225. In both treatments, dampings at 35° and at 120°F were approximately a fourth to a third of the dampings at the optimum temperatures.

22. It is apparent from the graphs of Appendix 9 that Treatment 225 was slightly superior to Treatment 198 at temperatures below about 55°F, but slightly inferior to it between 55° and 100°F. Considering the over all damping characteristics of the two treatments in the temperature range between 35° and 120°F, Treatment 225 might be considered as being only slightly inferior to the chromated felt Treatment 198.

DISCUSSION

23. Treatment 227 is the best treatment obtained to date with constrained layers of Paracril D stock 384-584. This treatment resulted from a study of the effects of thickness and the various factors associated with the shape of the constrained rubber layer on damping. Although it was not possible to ascertain the extent of the contributions of each one of these factors to damping, a combination of these effects yielded the above treatment, which exhibited about 30% more damping than a treatment utilizing a solid sheet constrained layer (Treatment 220).

24. The effect of temperature on the damping by Treatment 227 was not studied. The constrained layer of this treatment was prepared from the same stock as the constrained layer of Treatment 225. The effect of temperature on the damping of the two treatments should be very similar. Treatment 227 is also expected to

exhibit a damping maximum at about 65°F. Its damping at this temperature is likely to be somewhat higher than at 74°F. But at 74°F its average damping was only very slightly inferior to that of the chromated-felt Treatment 198. It is resonable to assume, therefore, that the dampings of the two treatments are nearly equal over the entire temperature range between 35° and 120°F.

CONCLUSIONS

25. The following conclusions apply to damping of 1-3/4 inch thick steel bars by treatments consisting of a 1-1/4 inch thick constraining layer of aluminum, and a constrained layer made of Paracril D stock 384-584.

a. Solid constrained layers 1/16 inch thick yield slightly higher damping than 1/8 and 1/4 inch thick layers.

b. Perforated constrained layers yield higher damping than solid sheet layers of the same thickness.

c. The best Paracril D treatment developed to date is Treatment 227. Its constrained layer is made of a 1/16 inch thick perforated sheet. The perforations are 1/4 inch square, and are separated by 1/4 inch wide rubber partitions.

d. Treatment 227 yields at 74°F nearly the same damping as Treatment 198 which utilizes chromated felt as a constrained layer.

e. Treatments utilizing constrained layers of stock 384-584 exhibit maximum damping at 65 F, and low damping at 35° and 120°F.

f. Damping tends to increase with increase of constraining pressure, but the effect is very slight in the pressure range between 15 and 70 psi.

FUTURE WORK

26. The Laboratory has developed a method for measuring the loss modulus of materials and proposes to investigate the possibility of using it for the selection or the development of damping materials. A special objective of this investigation would be the obtention of materials which are less sensitive to temperature than chromated felt or the Paracril D vulcanizate used in the present study.

PERSONNEL

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J. Oser, Technologist

Supervised by: R. R. James, Supervisory Technologist

Approved by: R. E. Morris

R. E. Morris, Principal Technologist

APPENDICES

1. Table. Description of Constrained Layer Damping Treatments and Damping of 1-3/4 Inch Thick Steel Bars at 75°F
2. Table. Dimensions of Perforated Constrained Damping Layers
3. Diagram. Schematic Layout of Instrumentation Used to Evaluate Damping Treatments
4. Table. Effect of Constraining Pressure and Thickness of Constrained Layer on Damping of 1-3/4 Inch Thick Steel Bars at 75°F
5. Graph. Effect of Thickness of Solid Sheet Constrained Layer on Damping of 1-3/4 Inch Thick Steel Bars at 75°F and 40 PSI Constraining Pressure
6. Graph. Effect of 1/16 Inch Thick Constrained Layers With and Without Perforations on the Damping of 1-3/4 Inch Thick Steel Bar at 75 F and 40 PSI Constraining Pressure
7. Graph. Effect of Temperature on Damping of 1-3/4 Inch Thick Steel Bar by Treatment 225 at 40 PSI Constraining Pressure
8. Table. Effect of Temperature on Damping of 1-3/4 Inch Thick Steel Bar by Treatment 225 at 40 PSI Constraining Pressure
9. Graph. Average Dampings Obtained at Various Temperatures with Treatments 198 and 225 Applied to 1-3/4 Inch Thick Steel Bar

DESCRIPTION OF CONSTRAINED LAYER DAMPING TREATMENTS AND DAMPING OF 1-3/4 INCH THICK STEEL BARS AT 75°F

Treatment No.	Type of Constrained Layer (1)	Thickness of Constrained Layer Inch	Shape Factor (2)	Mass Factor (3)	Area Factor (4)	Average Percent of Critical Damping at 75°F (5)	Frequency Range over which Damping was Equal to or Greater than 5% of Critical cps
221	Solid sheet	1/16	22.5	1.0	1.0	4.4	50-500
219	Solid sheet	1/8	11.5	2.0	1.0	4.1	50-300
220	Solid sheet	1/4	5.0	4.0	1.0	3.9	50-300
227	Perforated	1/16	2.85	0.75	0.75	6.2	50-1200
225	Perforated	1/16	1.3	0.5	0.50	5.5	100-1200
223	Perforated	1/4	0.7	3.0	0.75	4.2	50-400
224	Perforated	1/8	0.65	1.0	0.50	4.5	50-600

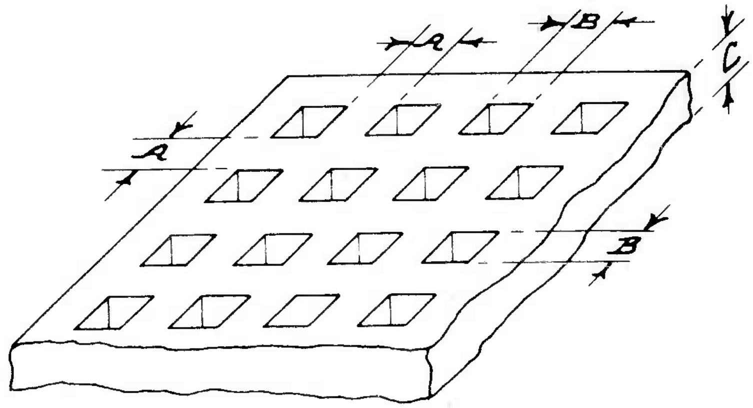
(1) Constrained layers were made of Paracril D stock 384-584. The constraining layer in each treatment was a 1-1/4 inch thick aluminum bar. Treatments were applied to one side of the steel bar and were subjected to an initial constraining pressure of 40 psi.

(2) Ratio of load bearing area of rubber in contact with steel bar to free area of rubber.

(3) Relative mass of rubber per unit area of treatment, based on 1/16 inch thick solid sheet.

(4) Ratio of load bearing area of rubber in contact with steel bar to treatment area.

(5) Average over the frequency range between 50 and 2000 cps.



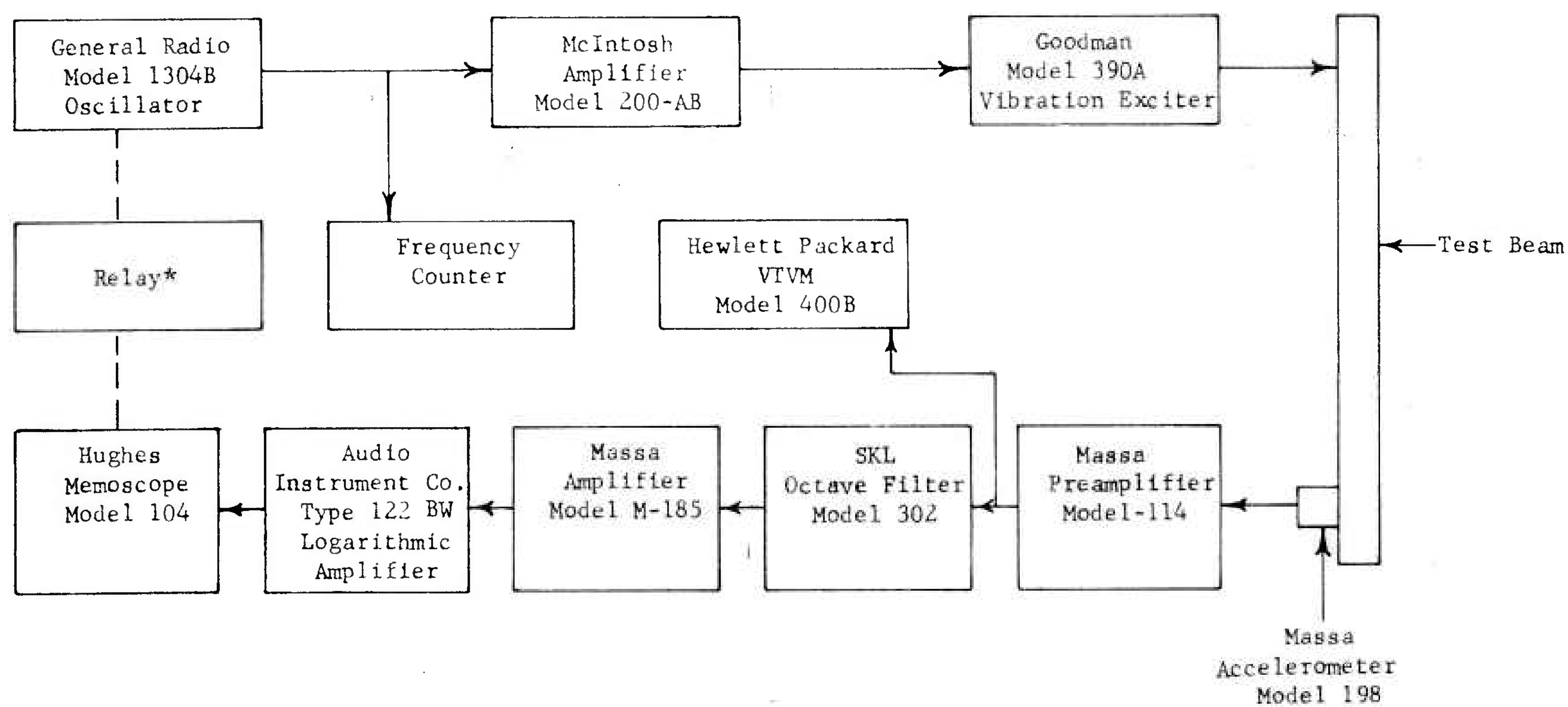
DIMENSIONS, INCHES

Treatment No.	A	B	C
223	0.250	0.250	1/4
224	0.146	0.354	1/8
225	0.146	0.354	1/16
227	0.250	0.250	1/16

NOTE: All perforations were on 0.50 inch centers.

DIMENSIONS OF PERFORATED CONSTRAINED DAMPING LAYERS

SCHEMATIC LAYOUT OF INSTRUMENTATION USED TO EVALUATE DAMPING TREATMENTS

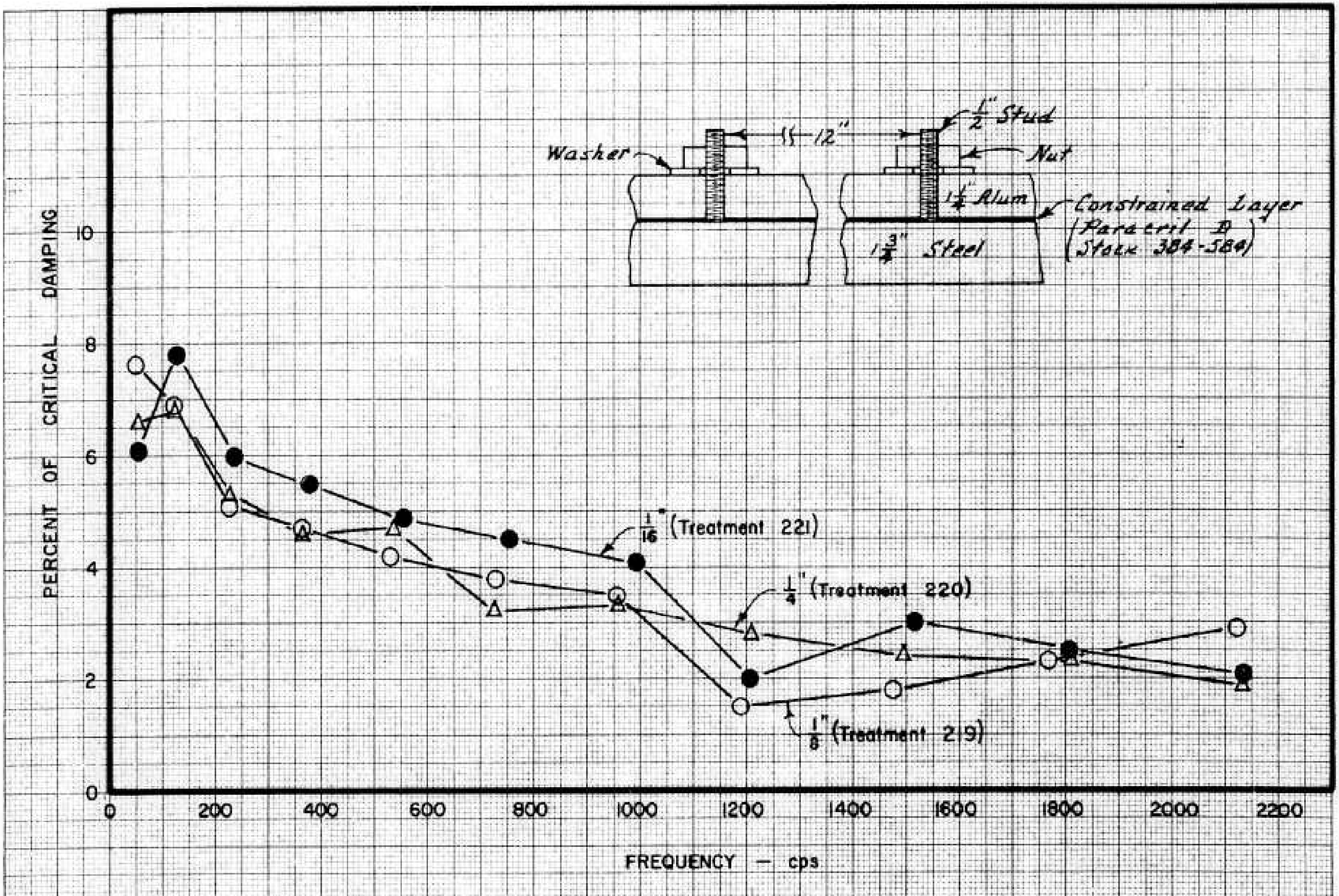


* Relay interrupts output of oscillator and simulataneously triggers scope.

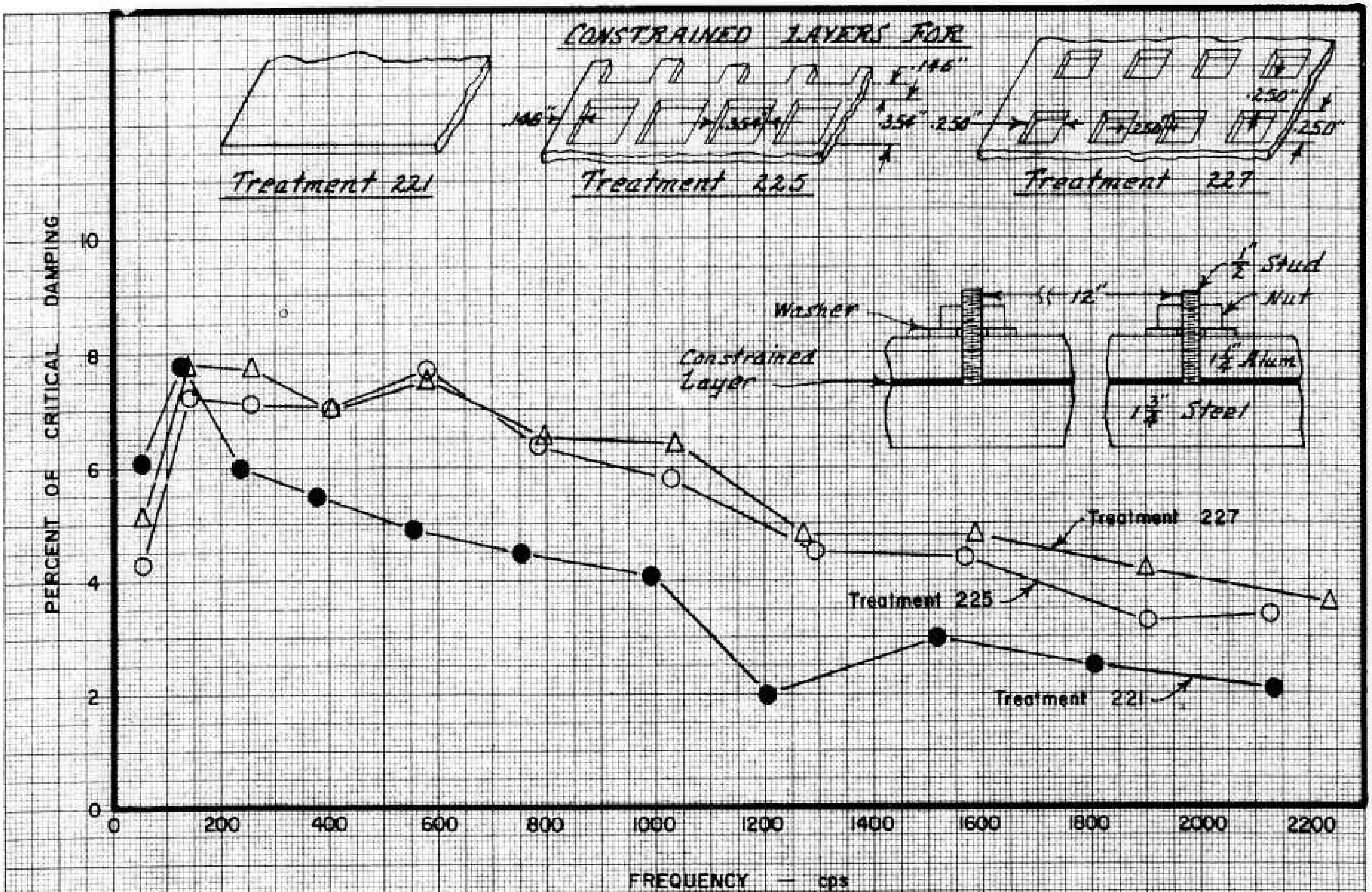
EFFECT OF CONSTRAINING PRESSURE AND THICKNESS OF CONSTRAINED LAYER ON DAMPING OF 1-3/4 INCH THICK STEEL BARS AT 75°F

Treatment No.	Thickness of Constrained Layer* Inch	Constraining Pressure, psi 15 — Average Per Cent of Critical Damping over Frequency Range of 50-2000 cps	Constraining Pressure, psi 40	Constraining Pressure, psi 73
221	1/16	4.3	4.4	5.0
219	1/8	3.8	4.1	4.4
220	1/4	2.9	3.9	3.8

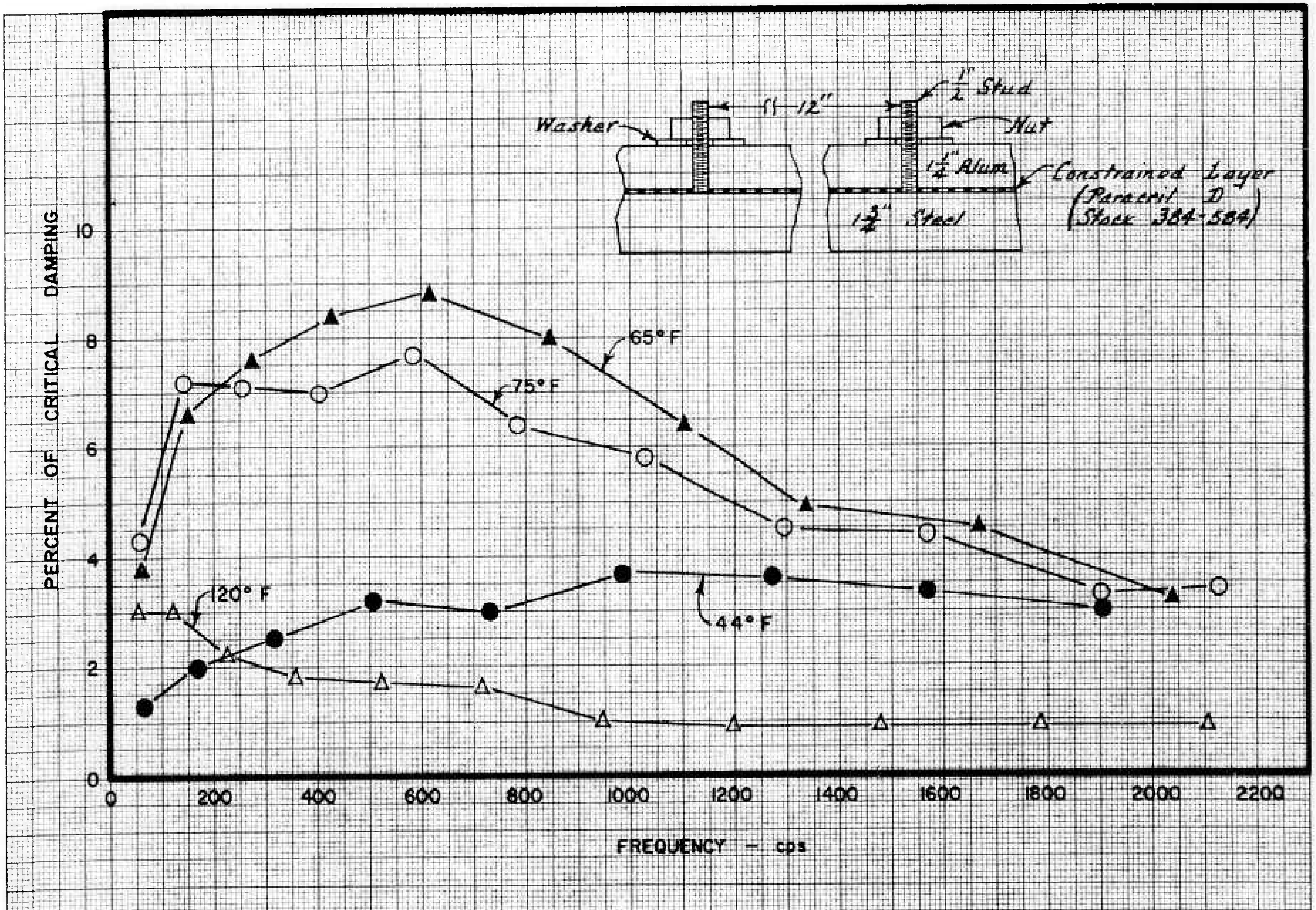
* Constrained layer consisted of a solid sheet of Paracril D stock 384-584. Constraining layer was a 1-1/4 inch thick aluminum bar.



EFFECT OF THICKNESS OF SOLID SHEET CONSTRAINED LAYER ON DAMPING
OF 1-3/4 INCH THICK STEEL BARS AT 75°F AND 40 PSI CONSTRAINING PRESSURE



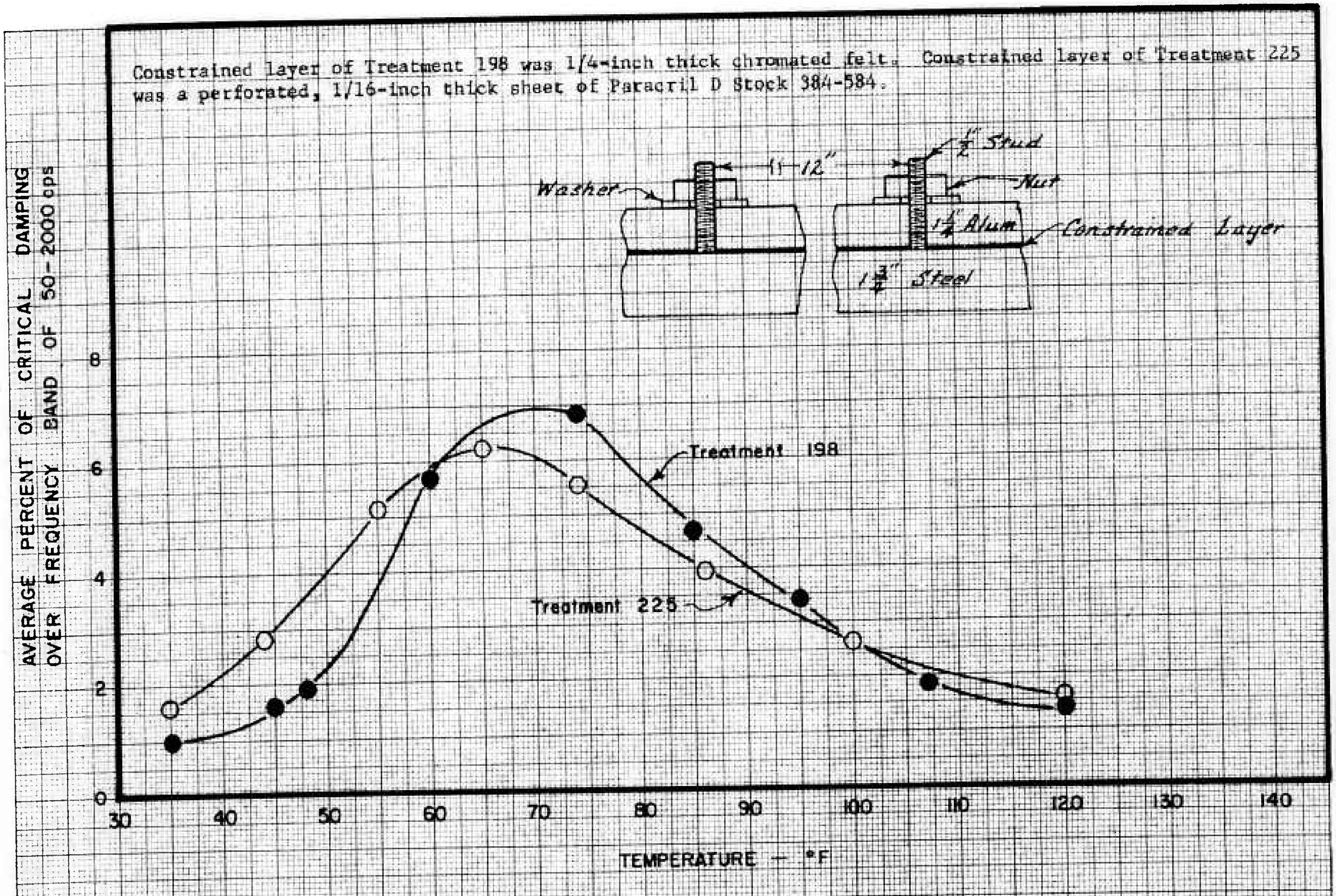
EFFECT OF 1/16 INCH THICK CONSTRAINED LAYERS WITH AND WITHOUT PERFORATIONS ON THE DAMPING OF 1-3/4 INCH THICK STEEL BAR AT 75°F AND 40 PSI CONSTRAINING PRESSURE



EFFECT OF TEMPERATURE ON DAMPING OF 1-3/4 INCH THICK STEEL BAR BY TREATMENT 225 at 40 PSI CONSTRAINING PRESSURE

EFFECT OF TEMPERATURE ON DAMPING OF 1-3/4 INCH THICK STEEL BARS
BY TREATMENT 225 AT 40 PSI CONSTRAINING PRESSURE

Temperature °F	Average Percent of Critical Damping over Frequency Range of 50-2000 cps	Frequency Range over which Damping was Equal to or Greater than 5% C/C_o cps
35	1.6	none
44	2.9	none
55	5.2	150-1500
65	6.2	100-1300
75	5.5	100-1200
86	4.0	100-250
100	2.7	none
120	1.6	none



AVERAGE DAMPINGS OBTAINED AT VARIOUS TEMPERATURES WITH TREATMENTS 198 AND 225 APPLIED TO 1-3/4 INCH THICK STEEL BAR

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DEVELOPMENT OF DAMPING TREATMENTS FOR NEW CONSTRUCTION SUBMARINES; PROGRESS REPORT NO. 12 by J. Oser

A constrained-layer type of damping treatment was developed for thick submarine plates. It consists of a 1-1/4 inch thick constraining layer of aluminum, and a 1/16 inch thick, perforated, constrained layer of Paracril D rubber. The weight ratio of treatment to steel is 1:4. The treatment, when applied to a 1-3/4 inch thick steel bar, yielded at 75°F an average damping of 6% of critical, over the frequency range of 50 to 2000 cps. A similar treatment, in which the constrained layer was made of the same Paracril D vulcanizate, exhibited maximum damping at 65°F. Its average damping at 35° and 120°F was one quarter to one third of average damping at 65°F.

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